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Is the 2003 SARS epidemic over? Long-term effects of epidemic exposure on mortality among older adults[☆]

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ABSTRACT

Infectious diseases put health of millions at risk and induce large socioeconomic costs each year. However, the long-term effects of exposure to infectious diseases on the elderly have received minimal attention. Using data from the Chinese Longitudinal Healthy Longevity Survey, this study adopts a differences-in-differences strategy to evaluate the long-term effects of epidemic exposure on old-age mortality. We find that intense exposure to the severe acute respiratory syndrome (SARS) epidemic led to an increase in old-age mortality after the SARS outbreak. We provide some suggestive evidence that exposure to SARS increased psychological stress and limitations in physical activities among old people.

1. Introduction

Infectious diseases pose a critical and continuing threat to public health. Over the past 20 years, the world has experienced global epidemics of severe acute respiratory syndrome (SARS), avian influenza (H5N1), swine flu (H1N1), meningitis, Ebola, and 2019 novel coronavirus (2019-nCoV). As the worldwide population ages, the adverse effects of infectious diseases may increase due to the vulnerability of old people (Lee & Mason, 2011).[1] Although much has been written on the instantaneous physical and socio-economic effects of disease epidemics, limited attention has been given to their long-term effects on old-age health outcomes (Laxminarayan & Malani, 2006; Perrings et al., 2014).

This study investigates whether and to what extent the panic caused by SARS, a lethal infectious disease, affected old-age mortality. The disease broke out in November 2002 in the Chinese province of Guangdong. It claimed 349 lives with 5327 probable cases reported in mainland China and fostered a sense of panic among the public. The regional and temporal variations in SARS exposure allow us to implement a differences-in-differences (DID) strategy. Our data are mainly from the Chinese Longitudinal Healthy Longevity

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[1] Old adults are especially sensitive to their physical and social surroundings and may be more vulnerable than young adults to the negative effects of psychological stress on health and survival (Böttche, Kuwert, & Knaevelsrud, 2012; Zeng, Gu, Purser, Hoenig, & Christakis, 2010). A. Liu et al. (2006) reported that the elderly were susceptible to psychological disorders one year after a severe flood in Hunan, China. Jia et al. (2010) found that compared with young adults, the elderly were more likely to develop psychological distress one year after the 2008 Sichuan earthquake.

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Survey (CLHLS). We quantify SARS exposure as the duration of SARS.

We find that the exposure to SARS led to an increase in the mortality of the elderly after the prevalence of SARS, and its adverse effect became considerably evident over time. A major methodological concern, however, is that SARS exposure may not be orthogonal to unobservable factors that affect health care outcomes. We address this concern in several ways, including parallel trend analysis, a placebo test using pseudo SARS exposure, testing for alternative measures of SARS exposure, and testing for sample selection. These tests lead us to believe in the causal link between SARS exposure and old-age mortality.

We provide an internally consistent explanation of how SARS exposure could increase old-age mortality. We provide some evidence that SARS exposure increased psychological stress and limitations in physical activities among old people. We also show that the adverse effect of SARS exposure was more significant among female and illiterate groups. Moreover, we find the introduction of social health insurance programs mitigated the adverse effect. However, the determination of the underlying mechanism is beyond the scope of our study.

Our study contributes to two threads of literature. First, it relates to a large body of empirical literature on the socioeconomic consequences of contagious diseases. In addition to negative instantaneous macroeconomic effects (Adda, 2016; Karlsson, Nilsson, & Pichler, 2014; Keogh-Brown, Wren-Lewis, Edmunds, Beutels, & Smith, 2010), contagious diseases may exert adverse effects on the long-term outcomes of vulnerable individuals (Aizer & Currie, 2014). Almond (2006) used decennial census data from the United States and found that cohorts in utero during the 1918 influenza pandemic had lower educational attainment and higher probabilities of being disabled decades later. Myrskylä, Mehta, and Chang (2013) reported cohorts born during the 1918 influenza pandemic peaks had excess all-cause mortality. Kelly (2011) revealed that the 1957 flu epidemic in the United Kingdom had significant negative effects on childhood physical and cognitive development. Hong (2013) showed that exposure to a malarial environment in early life substantially increased the likelihood of having various chronic diseases and not working in old age. The adverse psychological impact of infectious disease epidemics might persist among vulnerable groups.

Second, our study contributes to the literature on the impact of psychological stress on health outcomes (Garfin, Thompson, & Holman, 2018). There is increasing evidence that traumatic experiences are likely to lead to persistently elevated psychological symptomatology that may linger many years after exposure and increase individual morbidity and mortality (Friedman, Keane, & Resick, 2007). Marsland, Bachen, Cohen, Rabin, and Manuck (2002) conducted several laboratory experiments and showed that psychological stress affected immune function and predicted infectious disease susceptibility. Nakagawa et al. (2009) showed that stress arising from the Niigata-Chuetsu earthquake significantly increased long-term mortality from acute myocardial infarction in Japan. Giesinger et al. (2020) observed that posttraumatic stress disorder associated with the World Trade Center attacks in New York, on September 11, 2001 significantly increased mortality risk. Our study provides new empirical evidence of the long-term effect of stress derived from infectious diseases on the health outcomes of old adults.

The remainder of the article is structured as follows. Section 2 provides background information on the SARS outbreak. Section 3 introduces the data sets and empirical strategies. Section 4 presents the empirical results. The last section offers the conclusions.

2. Background

SARS was the first major new infectious disease of the 21st century and was unusual in its high morbidity and mortality rates. It started in the Chinese province of Guangdong in November 2002 and was recognized as a public health emergency of international concern in mid-March 2003. The epidemic had spread to 29 countries and 3 regions, with a cumulative total of 8422 cases and 916 deaths before it was contained in July 2003. China was the country hardest hit by SARS. The contagious disease had spread to over 20 provinces, municipalities, and autonomous regions, including Hong Kong and Taiwan. It claimed 349 lives with 5327 probable cases reported in mainland China since November 2002. The infection rate of SARS varied across provinces. The hardest hit areas were Guangdong, Beijing, Shanxi, and Inner Mongolia.

SARS is caused by a new coronavirus. It is transmitted primarily through droplets and its incubation period can range from 7 to 10 days. Infected patients may develop symptoms such as high fever, cough, dyspnea, lung disease, headache, muscle stiffness, loss of appetite, diarrhea, and disturbance of consciousness. No licensed pharmaceutical treatment specific for SARS was available during the epidemic. Thus, health authorities had resorted to traditional control tools of microbiology, including case isolation, infection control, and contact tracing.

Several aspects of the disease led to widespread anxiety during the outbreak (Smith, 2006). First, the cause of the outbreak remained unclear during the epidemic. Scientists had limited knowledge about the identity and nature of the pathogen. Thus, the probability and means of infection were difficult to be determined. People only knew that SARS was an airborne infectious disease with a high case-fatality ratio of approximately 10%. Second, uncertainties remained about the degree of effectiveness of specific interventions or measures to reduce the probability or consequences of infection (Lau et al., 2005).

The SARS risk was widely perceived as fatal (Liu, Hammitt, Wang, & Tsou, 2005). Surveys conducted in Taiwan showed that the perceived fatality of SARS was 4.1 on a scale from 0 (no fatal) to 5 (extremely fatal) (Liu et al., 2005). People hoarded all possible protective equipment during the outbreak. Cold medicine was sold quickly. The price of Isatidis Radix, a traditional Chinese antiviral remedy, increased by 800% in several areas (Bennett, Chiang, & Malani, 2015). People rushed to purchase white vinegar and garlic, which were thought to prevent viruses. Thus, the prices of these commodities also soared. Public places were disinfected several times a day. People strongly eschewed restaurants, trains, and shopping centers (Bennett et al., 2015). Classes were suspended for millions of primary and secondary school students. In addition, quarantine and inspection stations were established on major commuting roads. Travelers were required to complete health declaration forms and temperature checks. All suspected SARS patients were required to remain isolated for monitoring and treatment, up to a maximum of 21 days (Siu & Wong, 2004).

The social cost incurred due to the epidemic was large. The estimated global macroeconomic impact of SARS was approximately US $3–10 million per case (Chou, Kuo, & Peng, 2004; Hai, Zhao, Wang, & Hou, 2004; Keogh-Brown & Smith, 2008; Lee & McKibbin, 2004). Although the number of deaths from SARS was relatively small compared with other infectious diseases, SARS might have a powerful negative psychological impact on the populations of many countries (Osterholm, 2005). Tansey et al. (2007) showed that the physical conditions of SARS patients continuously improved in the first year but that their mental health did not. Lam et al. (2009) revealed that the adverse psychological impact of SARS persisted and remained clinically significant among the survivors during the 4-year follow-up. Hawryluck et al. (2004) found that about one-third of survey respondents who were subject to quarantine for SARS exhibited symptoms of posttraumatic stress disorder and depression. They also showed that the longer duration of quarantine was correlated with an increased incidence of psychological disorders.

3. Data and empirical strategy

3.1. Data sources and descriptive statistics

Our data come from the CLHLS, which is collected by Peking University. The first round of the CLHLS was conducted in 1998. Six additional panels were collected in 2000, 2002, 2005, 2008, 2011, and 2014. The survey covered 23 of 31 Chinese provinces, representing 95% of the total population of mainland China. Half of the counties and cities were randomly chosen in each of the provinces. Detailed sampling procedures can be found elsewhere (Gu, 2008; Zeng, 2008).

The survey team aimed to interview all centenarians in selected counties or cities, along with one nearby octogenarian and one nonagenarian matched in accordance with geographical unit and sex. Deceased and lost respondents were replaced with new interviewees. The age and sex of each new interviewee at a subsequent wave were based on the person who was lost to follow-up or deceased within survey intervals. Since 2002, cohorts aged 65 to 79 had also been followed and randomly chosen from the neighborhood of centenarians on the basis of pre-designated age – sex ratios. The attrition rate of the CLHLS was moderate. Approximately 12–20% of respondents were lost to follow up depending on the survey year.

The data contain a wealth of information that covers topics such as economic activities, education outcomes, family dynamics and relationships, mental status, and cognitive ability. The CLHLS gathered mortality information for the respondents who died between waves in interviews from various sources. Death certificates were used when available, otherwise the reported date of death from a close relative was used and validated using neighborhood registries (Gu & Dupre, 2008).

We use four dummy variables to measure the mortality risk of old adults (Chen et al., 2007; Cheng, Liu, Zhang, Shen, & Zeng, 2015; Finkelstein, et al., 2012). These variables indicate whether the respondent surveyed in the last wave was deceased within certain time periods (survey interval; one, two and three years). We also calculate survival time of respondents who died between 1998 and 2014. For the survivors, survival time was the days from the last interview date to the current interview date. We then recode all survival time longer than 850 days as 850.

The survey contains five questions about psychological status: (1) Do you feel fearful or anxious? (2) Do you feel lonely and isolated? (3) Can you make your own decisions concerning personal affairs? (4) Do you feel useless? (5) Do you feel as happy as when you were young? Each question has five response options, namely, always, often, sometimes, seldom, and never. We create five dummy variables to indicate whether the respondent had these feelings (always/often/sometimes/seldom vs. never).

The survey also collects information on limitations in physical activities. We set six binary variables indicating whether the respondent needed help in performing any of six basic daily activities (bathing, dressing, toileting, indoor movement, continence, and eating). In addition, the survey gathers information on health behaviors including diet, smoking, substance use, and physical activity. We define five binary variables indicating whether the respondent reported certain health behavior (eating fruit every day, eating vegetables every day, smoking, drinking, and exercising regularly).[2]

The information on the morbidity, mortality, and duration of SARS is collected from one of the major search engines in China (www.sohu.com) and the WHO website. We quantify SARS exposure of respondents as the duration of SARS in their province. We choose this measure because the long duration of exposure to SARS could be one of the causes of psychological problems. For example, prolonged exposure to the SARS epidemic might be associated with a long period of psychological distress. The duration of SARS in each province is calculated from the report of the first SARS case in this province until June 25, 2003, when WHO removed mainland China from the list of SARS epidemic areas. We also use the morbidity and mortality rates of SARS epidemic in each province as alternative measures of SARS exposure. In addition, we collect SARS confirmed cases for each prefecture from various sources, including news media, research papers, and government websites. We conducted additional analysis using the prefecture level SARS information in the robustness part.

In our analysis of mortality outcomes, we use the full sample (survivors and the deceased) in waves 1998–2011. We exclude 11,102 respondents who are lost to a subsequent follow-up survey because their mortality information is unavailable. We then exclude 135 respondents aged less than 65 because the eligible respondents in the CLHLS are those old people aged 65 and over. We further exclude 264 respondents whose education information is missing. Our final sample includes 59,481 observations from 31,707 respondents. Owing to the data availability, the sample sizes for the regression analysis vary with outcomes. Table 1 provides descriptive statistics of the main variables. The average age was 87.8. Women accounted for over half of the group, 56.5% lived in rural areas, and 63.2% had

[2] Table A1 provides more detailed information about the construction of some main outcome variables.

no schooling. Among the old adults surveyed in the current wave, 38.8% died within the adjacent survey interval, 12.7% within one year, 28.9% within two years, and 45.7% within three years. In the part of mechanism analysis, we further restrict the sample to all survivors in waves 1998–2005. Table A2 provides descriptive statistics of other health outcome variables. The sample sizes for the regression analysis also vary with outcomes due to data availability.

Fig. A1 presents a heated map of SARS duration in China. We examine the correlation between SARS duration and socioeconomic factors at the provincial level in Table 2. In general, we find small and statistically insignificant correlations between SARS duration and socioeconomic factors, including the mortality and morbidity of infectious diseases, health care resources, and local economic condition.

Fig. 1 compares the mortality rate of provinces with different durations of SARS exposure. The mortality rate is defined as the proportion of old adults deceased during the last survey interval. The mortality rate of provinces with high SARS exposure was lower than that of provinces with low SARS exposure before 2003. However, the mortality rate of provinces with different SARS exposure converged after the 2003 SARS epidemic. The mortality rate of provinces with high SARS exposure was sometimes even higher than that of provinces with low SARS exposure. This finding suggests that the health outcomes of old adults might worsen due to exposure to the lethal infectious disease.[3]

Fig. 2 shows the adjusted patterns of survival curves stratified according to exposure subtypes. Old people who were surveyed after 2003 had a lower mortality risk than those surveyed before 2003. However, the decrease in the mortality risk of old people in provinces with low SARS exposure was much larger than that in provinces with high SARS exposure. The difference in the decrease in mortality risk increased as time went by and became stable after two years.

Note: The figure depicts the evolution of mortality rate in provinces with different duration of SARS exposure. The mortality rate is defined as the proportion of deceased old adults in the sample surveyed in the last survey. The solid line stands for provinces with less than 70 days of SARS exposure, representing 57.10% of the whole sample. The dashed line stands for provinces with more than or equal to 70 days of SARS exposure. The thick line indicates the year 2003.

Note: The figure depicts the survival curves of four groups stratified according to exposure status. The vertical axis gives the percentage of subjects surviving. The horizontal axis gives time after the start of the observation. The long-dash line stands for provinces with less than 70 days of SARS exposure before the SARS outbreak, the dash-dot line for more than or equal to 70 days of SARS exposure before the outbreak, the solid line for less than 70 days of SARS exposure after the outbreak, the short-dash line for more than or equal to 70 days of SARS exposure after the outbreak. The shadows around the survival curves indicate a 95% confidence interval.

3.2. Empirical strategy

We use a DID strategy to identify the effects of SARS exposure on the health outcomes of old people. We compare the relative change in the health outcomes of old people in the post-epidemic period relative to the pre-epidemic period among provinces that had various levels of SARS epidemic intensity. The difference between our estimates and a standard DID strategy is that we employ a continuous measure of the intensity of treatment (i.e., SARS epidemic intensity) and thereby capture more variation in the data (Nunn & Qian, 2011).

We estimate the following equations:

$$Y_{ipt} = \beta_1 \bullet SARS_p * Post + X_{ipt}\gamma + \alpha_p + \lambda_t + \varepsilon_{ipt},$$

where Y_{ipt} represents a given health outcome (e.g. mortality, physical health, and mental health status) for individual i of province p in year t. $SARS_p$ is a proxy variable for SARS exposure in province p in 2003.Post is an indicator for whether the outcome variable is observed after 2003. In our analysis of old-age mortality, the variable Post takes a value of 1 for respondents surveyed in 2002 because their mortality information during the later survey interval, one/two/three years was observed after 2003. X_{ipt} is a vector of observed individual variables that may vary over time (e.g., five-year age groups, gender, hukou status, and years of education).[4] α_p stands for province fixed effects, and λ_t represents survey year fixed effects. ε_{ipt} is an error term. To allow for arbitrary correlations in the outcomes of residents in the same province, we cluster the standard errors at the province level (Bertrand, Duflo, & Mullainathan, 2004).

The DID coefficient is β_1, which measures the change in the effect of SARS exposure pre- and post-epidemics. Any common macro changes are picked up by the time dummy. This approach identifies a change in the health outcome of old people due to the disease shock. The key identifying assumption is that without the SARS epidemic the trend in the outcome would have been the same across provinces whatever the epidemic intensity is. Treatment induces a deviation from this parallel trend.

We adopt the accelerated failure time (AFT) model to examine the effect of SARS exposure on survival time of old people. The AFT model is a parametric linear model for survival analysis. The dependent variable is the log of survival time and independent variables are the same as those in the OLS specification. A key assumption of the AFT model is the distribution of survival times. We use different

[3] Notably, there may be other confounding factors that correlate with both SARS exposure and mortality. We provide more careful quantitative analysis in the part of empirical analysis.

[4] One might wonder whether the skewness of years of education would bias our estimates. Our results remain similar when we control for fixed effects for years of education instead. These results are available upon request.

Table 1
Summary statistics of main variables.

Variable	Observation	Mean	Standard deviation	Minimum	Maximum
Demographic information					
Age	67,034	87.93	10.85	65	124
Female	67,034	1.57	0.49	1	2
Years of education	67,034	1.91	3.35	0	26
Rural	67,034	0.56	0.50	0	1
Illiterate	67,034	0.63	0.48	0	1
Year	67,034	2004	4.17	1998	2011
Mortality information					
Mortality within the survey interval	67,034	0.33	0.47	0	1
Mortality within 1 year	65,996	0.13	0.33	0	1
Mortality within 2 years	65,229	0.29	0.45	0	1
Mortality within 3 years	58,314	0.46	0.50	0	1
Survival time (day)	65,996	712.06	234.44	0	850
Provincial level SARS information					
Number of cases	23	219.04	596.57	0	2521
Number of deaths	23	13.83	40.90	0	192
infection rate	23	0.10	0.37	0	1.77
death rate	23	0.01	0.03	0	0.13
Duration (100 days)	23	0.85	0.50	0	2.21
Prefectural level SARS information					
Number of cases	185	25.50	209.54	0	2521
Infection rate(1/100000)	185	0.03	0.22	0	2.22

Note: The data on old adults come from the 1998–2011 CLHLS. The information on SARS is collected from news media, research papers, and government websites.

Table 2
Correlation between SARS duration and macroeconomic variables.

Variable	correlation	*p*-value
Morbidity rate of notifiable infectious diseases (1/100,000)	0.007	0.974
Mortality rate of notifiable infectious diseases (1/100,000)	0.331	0.123
Health technicians per 1000 population	0.103	0.640
Practicing (assistant) physicians per 1000 population	0.105	0.634
Registered nurses per 1000 population	0.121	0.583
Hospital beds per 1000 population	0.045	0.840
Number of general hospital	0.065	0.767
GDP per capita (yuan)	0.161	0.464
Fiscal revenue per capita (yuan)	0.270	0.216
Fiscal expenditure per capita (yuan)	0.223	0.306
Total population (10,000 people)	0.240	0.269
Elderly people 65 years and over (10,000 people)	0.218	0.317
Population mortality rate (‰)	−0.007	0.974
Life expectancy in 2000	0.073	0.742

Note: The sample is 23 provinces surveyed by the CLHLS. The table presents the correlation coefficients between SARS duration and socioeconomic variables in 1967 and their significance levels.

distribution assumptions (log-normal, log-logistic, and gamma distribution) to examine the sensitivity of model specifications.[5]

4. Empirical results

4.1. Baseline results

Table 3 reports our baseline results. We quantify SARS exposure as SARS duration in a province. The dependent variable in Column (1) is a dummy variable indicating whether the survey respondent died during the later survey interval. The econometric analysis confirms our visual impression, that is, SARS exposure significantly increased the mortality risk of old people. One way to get a sense of

[5] Some dependent variables, such as mortality, psychological status, mental health status, and limitations in activities of daily living, are binary variables. We have run the estimation method of the limited dependent variable and our results remain robust. These results are available upon request.

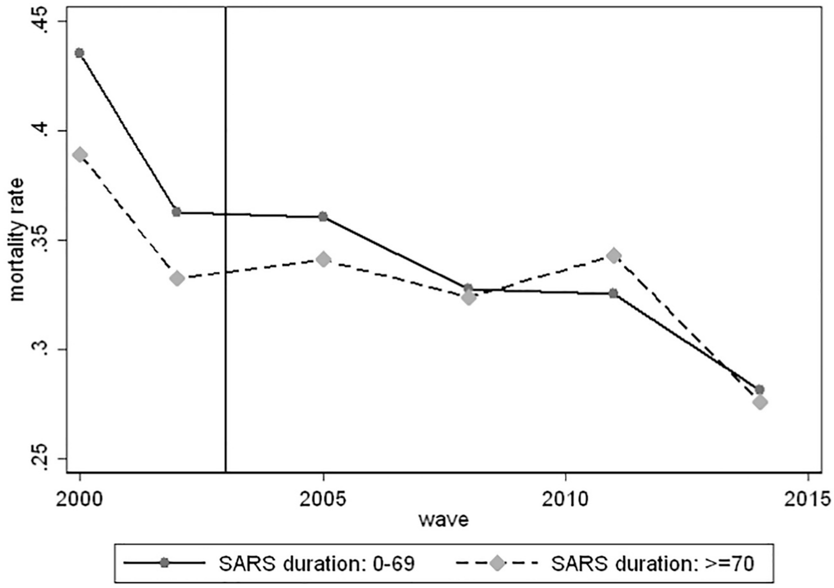

Fig. 1. Evolution of mortality rate.

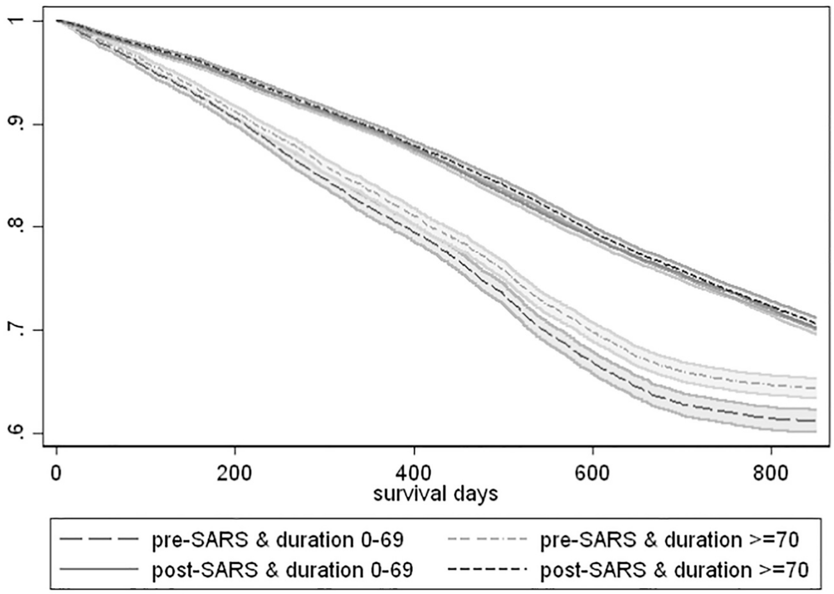

Fig. 2. Survival analysis.

its magnitude is as follows. The province at the 75th percentile of SARS exposure (1.35) is Sichuan Province. The province at the 25th percentile of SARS exposure (0.65) is Shandong Province. The estimated coefficient then implies that the mortality rate of old adults in Sichuan Province increased 2.3% faster than that of old adults in Shandong Province after the SARS epidemic.

The dependent variables in Columns (2) to (4) are whether the respondent surveyed in the current wave died during the succeeding one/two/three years. The estimates are consistent with our visual impression, that is, SARS exposure increased the mortality rate of old people surveyed in the last wave moderately in the first year. Then, the effect increased in the second year, and it became stable in the third year.[6]

Table 4 reports our estimates from the AFT model. The dependent variable is the log of survival time, and independent variables are the same as those in the OLS model. Columns (1) to (3) present results from the log-normal, log-logistic, and gamma models,

[6] Our results remain similar when we exclude the observations whose survival time is zero day. These results are available upon request.

Table 3
Baseline results.

Variables	(1)	(2)	(3)	(4)
	Deceased in the next wave	Deceased within 1 year	Deceased within 2 years	Deceased within 3 years
Duration*post2003	0.033***	0.015**	0.034***	0.032***
	(0.009)	(0.007)	(0.010)	(0.011)
Observations	67,034	65,996	65,229	58,314
R-squared	0.197	0.064	0.147	0.219
Year FE	YES	YES	YES	YES
Province FE	YES	YES	YES	YES
Age group FE	YES	YES	YES	YES
Other control	YES	YES	YES	YES

Note: Other control variables include a dummy for females, a dummy for rural areas, and years of education. Robust standard errors clustered at the provincial level are reported in parentheses. Wild-cluster bootstrap-t *p*-values are reported in brackets. ***significant at 1% level, **at 5%, *at 10%.

respectively. The results are insensitive to the specifications of the survival models and indicate that SARS exposure significantly decreased survival time of old adults. The 25th percentile of survival time is 625 days in the sample. The estimated coefficients imply that an increase of 100 days of SARS exposure reduced survival time of old adults at the 25th percentile of survival time by 46 to 53 days after the SARS epidemic.

4.2. Sensitivity analysis

We conduct a range of robustness tests, namely, checking for parallel trends prior to treatment assignment, a permutation test using randomly assigned treatment intensity, excluding the influence of other policies that might have been running at the same time, and testing for sample selection and functional form. In general, our findings remain robust. We report the results in the appendix.

Parallel trends. – A potential problem with DID is that it may confound the dynamic effects of SARS exposure with pre-existing differences in time trends across treated and untreated groups. In other words, provinces considerably exposed to SARS might have experienced deterioration in health outcomes after the epidemic due to differences in time trends that preceded SARS. Three approaches are considered to address this issue.

First, we allow the survey wave effect to vary with the predetermined province characteristics that may be correlated with SARS exposure across provinces. We add the interactions of survey year dummies and provincial characteristics in 2002, including infectious disease morbidity and mortality, health care resources, and macroeconomic conditions. The results are presented in Panels A to C of Table A3. The estimated SARS exposure effect has a magnitude close to the benchmark results and is significant at the conventional level.

Second, we examine whether provinces with different SARS exposure had parallel pretreatment trends. We interact the survey wave dummies with the duration of the SARS epidemic in each province. The omitted time category is the 1998 wave. The results are reported in Panel D of Table A3. The coefficients on the interaction term of the 2000 wave dummy and SARS exposure are small and statistically insignificant, suggesting that the treatment and control provinces followed similar time trends before the SARS outbreak. However, the mortality risk in provinces with high SARS exposure increased much faster than that in provinces with low SARS exposure after the SARS epidemic.

Third, we conduct a permutation test (Rosenbaum, 2007). Specifically, we draw 1000 placebo treatment days for each province from the full support of the potential days of the estimation sample, 0–222, and then re-estimate the baseline models. Fig. A2 presents the histogram graphs for these estimates. The thick line indicates the estimation results using the true treatment level. The placebo treatment effect estimates are significantly different from the true estimate. The permutation test indicates that the sign and significance of our estimates are not merely driven by provincial differences unrelated to the effect of SARS exposure. Overall, the three approaches lend further credence to our identification strategy.

Possible contamination from other policy changes. – Our estimation strategy exploits an exogenous disease shock. We therefore need to check that the change we observe was due to SARS exposure rather than other shocks or policies that might have been running at the same time. One potential policy candidate was the New Rural Cooperative Medical Scheme (NRCMS), which was introduced around 2003 to expand the coverage of insurance in rural households. It provided allowances to rural residents, and its enforcement varied across provinces. It was possible that the enforcement of the NCRMS was correlated with both SARS exposure and health outcomes, therefore biasing our baseline estimates.

To test this possibility, we include in the regression a dummy variable indicating whether the respondent was enrolled in the NRCMS. The CLHLS did not collect information on social insurance until 2005. We assume that the respondent was not enrolled in the NRCMS before 2005.[7] Panel E of Table A3 presents our results with medical insurance controlled for. The estimates show that our results are stronger when controlling for the differences in medical insurance.

Other confounding factors and standard errors – To avoid inclusion of potentially endogenous variables, our baseline estimates

[7] According to China's National Bureau of Statistics, the participation rate was only 10.4% in 2004. The prior survey was conducted in 1998, 2000, and 2002. Therefore, our assumption is reasonable.

Table 4
Survival analysis.

	Dependent variable: log(survival time)		
	Log-normal	Log-logistic	Generalized gamma
	(1)	(2)	(3)
SARS duration*post	−0.074*	−0.078**	−0.084***
	(0.038)	(0.034)	(0.030)
Observations	65,989	65,989	65,989
Year FE	YES	YES	YES
Province FE	YES	YES	YES
Age group FE	YES	YES	YES
Other control	YES	YES	YES

Note: Columns (1) to (3) present estimates from accelerated failure time models using the log-normal, log-logistic, and gamma distributions, respectively. Other control variables include a dummy for females, a dummy for rural areas, and years of education. Standard errors are clustered by province. ***significant at 1% level, **at 5%, *at 10%.

control only for some basic predetermined individual characteristics. It is possible that there are omitted variables potentially correlated with SARS exposure that are driving our results. In Panel F of Table A3, we control for fixed effects for primary sources of financial support and marriage status.[8] In Panel G of Table A3, we include in our regressions a range of time-varying macroeconomic variables at the provincial level, including GDP, the number of hospitals, the number of physicians, and the number of hospital beds. The estimates of SARS exposure are almost the same as in the benchmark results in Table 3.

In our main analysis, we use robust standard errors clustered at the provincial level. We have 23 clusters. The small number of clusters might bias our standard errors downwards.[9] To address concerns about the small number of clusters, we perform 1000 draws of a wild-cluster bootstrap percentile t-procedure suggested by Cameron, Gelbach, and Miller (2008). In Panel H of Table A3, we present robust standard errors in parentheses as well as two-tailed wild cluster bootstrap *p*-values in square brackets. Our results remain robust.

Sample selection. – One might wonder whether the sample selection process biases our estimates. We drop those old adults who were lost to follow-up in our main analysis. If the sample attrition was not orthogonal to SARS exposure, our results might be biased. We include the lost-to-follow-up sample and formally test whether SARS exposure affected the sample attrition rate. We set a dummy variable indicating whether an old man dropped out from the study. The estimates presented in Column (1) of Table A4 suggest no significant impact of SARS exposure on the probability of being lost to follow-up. Since 2002, the survey has been expanded to include those aged 65 to 79. To determine whether the change of sample composition biased our results, we then exclude those aged 65 to 79 and redo our analysis. The results reported in Columns (2) to (5) of Table A4 are similar to our baseline results.

Measures for SARS exposure – In our previous analysis, we have assumed that exposure to SARS follows a simple linear function of SARS duration. As a robustness check, we quantify exposure to SARS as infection rate ranking, death rate ranking, infection rate, and death rate.[10] We report estimates using alternative measures of SARS exposure in Panels A to D of Table A5 and find qualitatively identical results. The estimates using death-related measures are less significant than others. A potential explanation is that the number of deaths may not be a good measure for SARS exposure. During the epidemic, people in provinces with SARS cases but no SARS deaths might have experienced more severe psychological distress than those in provinces with no SARS cases did.

One might doubt that SARS exposure at the provincial level contains large measure errors. There could be substantial heterogeneity of actual SARS exposure within the same provinces. Cities within the same province may have differential capacity to avoid harm from the epidemic at the local level. In addition, variations in SARS exposure at the provincial level may confound with some unobserved factors at the provincial level, such as clan culture, social normal, property institutions, and experiences of government officials.

We formally test whether the level of SARS exposure measurement biases our estimates. We rerun our baseline regressions using the prefectural level SARS infection rate as an alternative measure of SARS exposure and control for city, birth year, female, urban area, and survey wave dummies. The standard errors are clustered at the city level. We report the estimates in Panel E of Table A5. Reassuringly, the estimated effect of SARS exposure changes little. Overall, these estimates suggest minimal bias induced by the measurement of SARS exposure.

4.3. Potential mechanisms and other findings

We have established that old-age mortality risk increased faster in provinces with high SARS exposure than in provinces with low

[8] Possible sources of financial support include retirement wages, spouses, children, grandchildren, relatives, local government or community, work, and others. The types of marital status include single, married, widowed, divorced, separated, and cohabiting with a partner.

[9] There is no clear threshold for too few clusters. The number could vary between 20 and 50 (Cameron & Miller, 2015).

[10] The infection rate in Beijing is much larger than those in other provinces. We exclude Beijing when using the linear function of infection rate and death rate to measure SARS exposure. The estimates are similar if we include the Beijing sample and assume that the Beijing province has the same infection rate as Guangdong Province, which has the second largest infection rate.

SARS exposure. Due to data limitation, we cannot be conclusive about the underlying mechanism. In this subsection, we provide some suggestive evidence that old people experienced a decline in their psychological and physical well-being due to SARS exposure. We focus on surviving respondents surveyed before or during 2005. The corresponding estimates should be interpreted with caution because the health outcomes of old adults who died within the survey interval were not observed. If old adults died within the survey interval due to sharp declines in psychological and physical health status, our estimates should be downward biased. We do not include respondents surveyed after 2005 for the same reason.

Table 5 presents estimates for psychological status. The dependent variables in Columns (1) to (5) are dummy variables for anxiety and fear, isolation and loneliness, making own decisions, uselessness, and happiness, respectively. The results indicate that old people surveyed in provinces with high SARS exposure were more likely to feel anxious and fearful, lonely and isolated, and useless than those in provinces with low SARS exposure. SARS exposure had no obvious effect on the likelihoods of making their own decisions and being as happy as when the respondents were young.

Table 6 presents estimates for self-reported activities of daily living. The dependent variables are dummy variables indicating whether the respondent needed assistance in six daily activities (bathing, dressing, toileting, indoor movement, continence, and eating). The activities are essential and routine aspects of self-care. The results indicate that old people with high SARS exposure were more likely to have limitations in daily activities than those with low SARS exposure.

We have found that SARS exposure was associated with psychological distress, physical disability, and mortality risk. A potential explanation is that the exposure to traumatic stressors created long-lasting psychological distress among the elderly and then increased their risk of disability and mortality. This explanation is consistent with previous studies on the associations among psychological distress, physical activity, and mortality (Cuijpers & Schoevers, 2004). For example, Schoevers et al. (2000) found that psychological distress deterred participation in physical activity among older adults in Australia. Gu and Feng (2018) found that a high level of psychological distress was associated with a high mortality rate and poor health among the oldest old in China. Feng, Hoenig, Gu, Yi, and Purser (2010) showed that old adults with limitations in activities of daily living had significantly higher mortality risk than those without any limitations in China.

An alternative explanation is the change in health behaviors. SARS exposure might change old adults' attitudes toward health, thus altering their actions to maintain, attain, or regain good health and to prevent illness. Table 7 presents estimates for health behaviors including diet, smoking, substance use, and physical activity. The coefficients are small and statistically insignificant, which suggests minimal impact of SARS exposure on these health behaviors. Overall, there is little evidence that the associations between SARS exposure and old-age mortality could be explained by changes in health behaviors.

4.4. Heterogeneity analysis

We have established that the mortality rate of old people increased faster in areas with high SARS exposure than those in areas with low exposure. An important question is whether the long-term impact of SARS exposure or whether susceptibility and response varied. We study this issue in this subsection.

Table 8 presents heterogeneous effects of SARS exposure on old-age mortality across individuals. Men and women may differ in their reaction to psychological distress. Women may be more vulnerable than men to the effect of external stress, such as wartime events, loss of friends and relatives (Sibai et al., 2001). Columns (1) and (2) present gender-specific estimates. The results suggest that although SARS exposure had significantly negative effects on both men and women, the effect was more pronounced for women. We use the method of seemingly unrelated estimation to test the equality of coefficients across gender and find that the difference in the estimated effects is statistically significant.

Education is an important determinant of the health outcomes of old adults (Luo, Zhang, & Gu, 2015). The response of people to traumatic events may vary by their educational level. Those with low levels of education might lack protective knowledge or resources to cope with stress arising from the SARS epidemic. Columns (3) and (4) show estimates for literate and illiterate people, respectively. The estimates indicate that the illiterate old adults, but not the literate, had a significantly elevated mortality risk because of exposure to the SARS epidemic. The difference in the estimated effects for the illiterate and the literate is statistically significant.

Table 9 presents heterogeneous effects of SARS exposure across regions. The impact of SARS exposure may differ in urban and rural areas. On the one hand, urban residents were exposed to SARS more than rural residents were because most of the infected patients lived in urban areas. On the other hand, urban residents had more advantages than rural residents when coping with the SARS epidemic. Urban residents had higher income and could afford better social services. By contrast, timely care was less available to rural residents due to lack of health insurance or regular health care facilities. We estimate separate models for rural and urban residents. The results presented in Columns (1) and (2) indicate that the impact of SARS exposure on rural and urban residents was similar. Despite the high exposure to stressors arising from SARS, urban residents might respond properly thus having similar susceptibility to rural residents.

The reaction of the Chinese government after SARS, especially expanding health insurance coverage, may alleviate the negative effects of SARS exposure. In 2005, the CLHLS started to collect information on social health insurance, including the NRCMS, the Urban Resident Basic Medical Insurance (URBMI), and other social health insurance. We classify provinces with social health insurance coverage rate higher than the median level during 2005–2011 in the sample as areas with high coverage, which accounted for 48.0% of the whole sample. We classify other provinces as areas with low coverage.

Table 5
Psychological status.

	(1)	(2)	(3)	(4)	(5)
Variables	Anxiety	Isolation	Decision	Uselessness	Happiness
SARS duration*post	0.073***	0.049**	0.010	0.043**	0.015
	(0.022)	(0.020)	(0.014)	(0.016)	(0.016)
Observations	46,163	46,149	45,535	45,754	44,862
R-squared	0.127	0.124	0.017	0.066	0.021
Year FE	YES	YES	YES	YES	YES
Province FE	YES	YES	YES	YES	YES
Age group FE	YES	YES	YES	YES	YES
Other control	YES	YES	YES	YES	YES

Note: The CLHLS contains five questions about current psychological status: (1) Do you feel fearful or anxious? (2) Do you feel lonely and isolated? (3) Can you make your own decisions concerning personal affairs? (4) Do you feel useless? (5) Do you feel as happy as when you were young? The dependent variables are dummy variables indicating whether the respondent had these feelings (always/often/sometimes/seldom vs. never). Other control variables include a dummy for females, a dummy for rural areas, and years of education. The sample is restricted to old adults surveyed before and in 2005. Standard errors are clustered by province. ***significant at 1% level, **at 5%, *at 10%.

Table 6
Limitations in activities of daily living.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	Bathing	Dressing	Toileting	Movement	Continence	Eating
SARS duration*post	0.034**	0.008*	0.014**	0.009**	−0.001	0.011**
	(0.014)	(0.004)	(0.005)	(0.004)	(0.007)	(0.005)
Observations	51,542	51,620	51,620	51,604	51,612	51,614
R-squared	0.220	0.101	0.113	0.096	0.039	0.072
Year FE	YES	YES	YES	YES	YES	YES
Province FE	YES	YES	YES	YES	YES	YES
Age group FE	YES	YES	YES	YES	YES	YES
Other control	YES	YES	YES	YES	YES	YES

Note: The dependent variables in Columns (1) to (6) are dummy variables indicating whether the respondent needed assistance in bathing, dressing, toileting, indoor movement, continence, and eating. Other control variables include a dummy for females, a dummy for rural areas, and years of education. The sample is restricted to old adults surveyed before and in 2005. Standard errors are clustered by province. ***significant at 1% level, **at 5%, *at 10%.

Table 7
Health behaviors.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	Food	Fruit	Vegetable	Smoking	Drinking	Exercise
SARS duration*post	0.059	0.013	0.007	−0.006	−0.015	−0.014
	(0.089)	(0.012)	(0.040)	(0.016)	(0.014)	(0.022)
Observations	44,267	51,611	51,608	51,589	51,578	51,578
R-squared	0.177	0.120	0.098	0.131	0.072	0.129
Year FE	YES	YES	YES	YES	YES	YES
Province FE	YES	YES	YES	YES	YES	YES
Age group FE	YES	YES	YES	YES	YES	YES
Other control	YES	YES	YES	YES	YES	YES

Note: The dependent variable in Column (1) is the amount of daily staple food consumption. The dependent variables in Columns (2) to (6) are five binary variables indicating whether the respondent reported certain health behavior (eating fruit every day, eating fruit every day, smoking, drinking, and exercising regularly). Other control variables include a dummy for females, a dummy for rural areas, and years of education. The sample is restricted to old adults surveyed before and in 2005. Standard errors are clustered by province. ***significant at 1% level, **at 5%, *at 10%.

Table 8
Individual heterogeneity analysis.

	The dependent variable: whether the respondent was deceased within the survey interval			
	(1)	(2)	(3)	(4)
	Male	Female	Illiterate	Literate
SARS duration*post	0.025**	0.038***	0.049***	−0.001
	(0.011)	(0.009)	(0.008)	(0.015)
Observations	28,498	38,536	42,453	24,581
R-squared	0.180	0.206	0.180	0.194
Year FE	YES	YES	YES	YES
Province FE	YES	YES	YES	YES
Age group FE	YES	YES	YES	YES
Other control	YES	YES	YES	YES

Note: The dependent variable is a binary variable indicating whether the respondent was deceased within survey interval. The regressions in Columns (1) and (2) control for years of education and a dummy for rural areas. The regressions in Columns (3) and (4) control for a dummy for females, a dummy for rural areas, and years of education. Standard errors are clustered by province. ***significant at 1% level, **at 5%, *at 10%.

Table 9
Regional heterogeneity analysis.

The dependent variable: whether the respondent was deceased within the survey interval				
	(1)	(2)	(3)	(4)
	Urban	Rural	High health insurance coverage	Low health insurance coverage
SARS duration*post	0.034**	0.035***	0.026	0.038***
	(0.012)	(0.010)	(0.017)	(0.008)
Observations	29,223	37,811	29,576	37,458
R-squared	0.192	0.201	0.214	0.184
Year FE	YES	YES	YES	YES
Province FE	YES	YES	YES	YES
Age group FE	YES	YES	YES	YES
Other control	YES	YES	YES	YES

Note: The dependent variable is a binary variable indicating whether the respondent was deceased within survey interval. Other control variables include a dummy for females, a dummy for rural areas, and years of education. Standard errors are clustered by province. ***significant at 1% level, **at 5%, *at 10%.

We begin by investigating the correlation between SARS exposure and social health insurance coverage rate during 2005–2011. The correlation coefficient is small (−0.08) and statistically insignificant, which suggests that local governments expanded health insurance coverage after SARS regardless of the severity of SARS exposure. Columns (3) and (4) report separate estimates for provinces with high and low coverage of social health insurance. The estimates indicate that although SARS exposure had significantly negative effects in both areas, the effect was larger in areas with low coverage of social health insurance. A potential explanation is that investments in the healthcare system may mitigate the adverse effects of contagious disease epidemics in the long run.[11]

5. Conclusions

Infectious diseases can threaten the health of millions. Greater appreciation of the possible impact of infectious diseases might help manage infectious disease outbreaks. Using data from the CLHLS, this study adopts a DID strategy to assess the long-term effects of SARS exposure on old-age mortality. We find that exposure to SARS increased mortality risk among old people after the SARS epidemic. A potential explanation is that SARS exposure increased psychological stress among the elderly, thus deteriorating their health status.

The findings of this study open up several avenues for future research. First, our study indicates that adverse consequences of SARS exposure stretched well beyond the immediate material and psychological effects they determined and might have a long-run impact

[11] Note that other explanations may play an important role in accounting for the differential effects of SARS exposure across areas. For example, it may be the case that health behaviors may correlate with health insurance and health behaviors can mitigate the adverse effects of SARS exposure.

on old-age health. The COVID-19 pandemic is having a devastating human toll and imposing an unprecedented shock to the world's economy. It is unclear whether old people will suffer from constant psychological stress and remain unhealthy after the pandemic. Researchers and government may pay close attention to the health status of old people during and after the pandemic. Adverse health and economic effects can be alleviated by early detection and response.

Second, we show that female and illiterate elderly are more vulnerable to the adverse effects of the epidemic. The disadvantaged group may lack information about infectious diseases and may not get help from others if infected. These factors may make them feel more anxious and fearful during the epidemic. At present, little is known about how expertise information on contagious diseases affects behavioral response. Assessing the role of expertise information on individual response to the epidemic is important for government intervention.

Third, we observe that the adverse effect of SARS is less pronounced in areas with high health insurance coverage. One potential explanation is that social health insurance can alleviate the negative effects of SARS during and after the epidemic. After SARS, the Chinese government strengthened its role in health care sectors. The New Rural Corporative Medical Scheme and the Urban Resident Basic Medical Insurance were piloted in 2003 and 2007 respectively. Afterwards, the coverage of social health insurance expanded dramatically, almost reaching universal coverage in 2015. Previous studies have assessed the effects of these health insurance programs and have found an increase in health care utilization (Cheng et al., 2015; Pan, Lei, & Liu, 2016; Yip et al., 2019). However, we still have limited knowledge about how government interventions, such as public health insurance, mental health services, and public health education, can reduce the long-run negative effects of the epidemic. There is a need for a better understanding of the long-run effectiveness of government interventions during and after the epidemic.

Appendix A. Robustness check

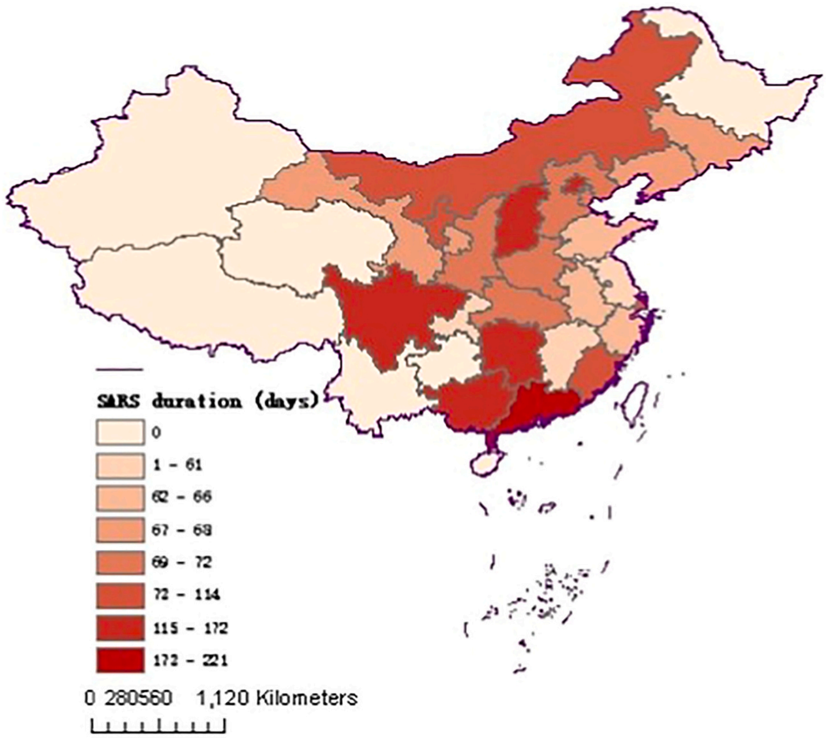

Fig. A1. SARS duration across provinces.

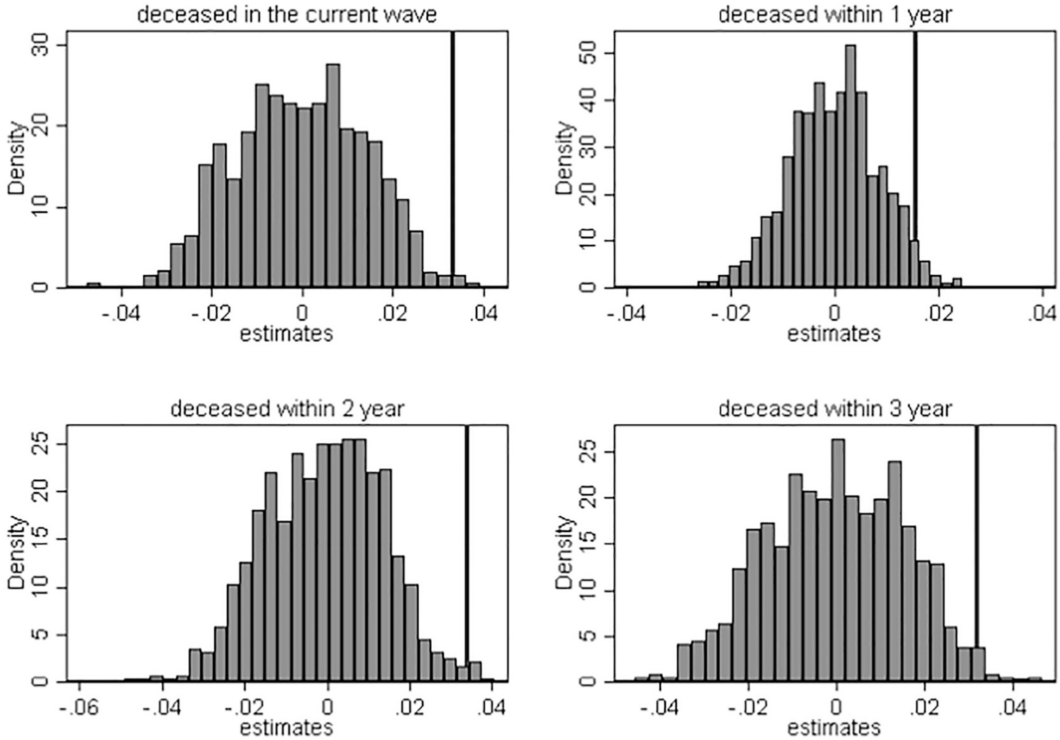

Fig. A2. Estimates from permutation placebo tests.

Note: We randomly assign the duration of SARS epidemics to provinces and construct the "placebo" SARS exposure based on the simulated SARS duration and survey year, using the baseline sample. The histogram displays the distributions of the placebo estimates from 1000 random assignments.

Table A1
Outcome Variables and Corresponding Survey Questions.

Variable	Corresponding question	Variable construction
Mortality within survey interval	Did the interviewee die within the survey interval?	1-yes; 0-no
Anxiety	Do you often feel fearful or anxious?	1-always/often/sometimes/seldom; 0-never
Isolation	Do you often feel lonely and isolated?	
Decision	Can you make your own decisions concerning your personal affairs?	
Useless	Do you feel that the older you get, the more useless you are?	
Happy	Are you as happy as when you were younger?	
staple food	How much of staple food do you normally eat per day?	Continuous variable
Fruit	How often do you eat fresh fruit?	1-almost every day; 0-almost every day except winter (always)/
Vegetable	How often do you eat vegetables?	occasionally/rarely or never
Smoking	Do you smoke at the present time?	1-yes; 0-no
Drinking	Do you drink alcohol at the present time?	
Exercise	Do you do exercises regularly at present?	
Bathing	Do you need help with bathing?	1-receives assistance in bathing for more than one part of the body/
Dressing	Do you need help with dressing?	for part of the body;0-no assistance
Toileting	Do you need help with toileting?	
Movement	Do you need help with movement?	
Continence	Do you need help with continence?	
Eating	Do you need help with eating?	

Table A2
Summary statistics of additional heath outcome variables.

Variable	Observation	Mean	Standard Deviation	Minimum	Maximum
Psychological factors					
Anxiety	46,163	0.676	0.468	0	1
Isolation	46,149	0.683	0.465	0	1
Decision	45,535	0.955	0.208	0	1
Useless	45,754	0.846	0.361	0	1
Happy	44,862	0.928	0.258	0	1
Health behaviors					
Staple food	44,267	5.508	2.488	1	15
Fruit	51,611	0.133	0.340	0	1
Vegetable	51,608	0.594	0.491	0	1
Smoking	51,589	0.180	0.385	0	1
Drinking	51,578	0.208	0.406	0	1
Exercise	51,578	0.309	0.462	0	1
Limitations in physical activities					
Bathing	51,542	0.273	0.446	0	1
Dressing	51,620	0.138	0.345	0	1
Toileting	51,620	0.149	0.356	0	1
Movement	51,604	0.123	0.328	0	1
Continence	51,612	0.073	0.261	0	1
Eating	51,614	0.092	0.289	0	1

Note: The data on old adults come from the 1998–2005 CLHLS.

Table A3
Sensitivity analysis.

Variables	(1)	(2)	(3)	(4)
	Mortality within	Mortality within	Mortality within	Mortality within
	Survey interval	1 year	2 years	3 years
Panel A. Infectious disease				
SARS duration*post	0.034***	0.020**	0.040***	0.040***
	(0.009)	(0.009)	(0.011)	(0.012)
Panel B. Heath care				
SARS duration*post	0.038***	0.020**	0.042***	0.042***
	(0.008)	(0.009)	(0.010)	(0.011)
Panel C. Macroeconomic				
SARS duration*post	0.036***	0.017**	0.035***	0.032***
	(0.011)	(0.007)	(0.009)	(0.011)
Panel D. Parallel trend analysis				
1(year = 2000)*SARS duration	−0.003	0.005	−0.005	0.009
	(0.012)	(0.010)	(0.018)	(0.014)
1(year = 2002)* SARS duration	0.030***	0.020**	0.034***	0.024
	(0.009)	(0.009)	(0.008)	(0.017)
1(year = 2005)* SARS duration	0.033**	0.023**	0.038***	0.034**
	(0.013)	(0.011)	(0.009)	(0.014)
1(year = 2008)* SARS duration	0.026**	0.015	0.024**	0.029**
	(0.012)	(0.009)	(0.011)	(0.012)
1(year = 2011)* SARS duration	0.041**	0.012	0.028**	0.127*
	(0.016)	(0.010)	(0.012)	(0.067)
	(0.009)	(0.007)	(0.010)	(0.011)
Panel E. Health insurance				
SARS duration*post	0.033***	0.015**	0.034***	0.032***
	(0.009)	(0.007)	(0.010)	(0.011)
Panel F. Individual characteristics				
SARS duration*post	0.034***	0.014*	0.035***	0.032**
	(0.009)	(0.008)	(0.011)	(0.013)
Panel G. Time-varying socioeconomic factors				
SARS duration*post	0.033***	0.015**	0.033***	0.032***
	(0.008)	(0.007)	(0.009)	(0.011)
Panel H. Wild bootstrap p-value				
SARS duration*post	0.033***	0.015**	0.034***	0.032***
	(0.009)	(0.007)	(0.010)	(0.011)
	[0.044]	[0.117]	[0.053]	[0.064]

(continued on next page)

Table A3 (*continued*)

Variables	(1) Mortality within Survey interval	(2) Mortality within 1 year	(3) Mortality within 2 years	(4) Mortality within 3 years
Observations	67,034	65,996	65,229	58,314
Year FE	YES	YES	YES	YES
Province FE	YES	YES	YES	YES
Age group FE	YES	YES	YES	YES
Other control	YES	YES	YES	YES

Note: All cells report the DID estimates from separate regressions. We interact the survey wave dummies with socioeconomic factors in 2003 to control differential trends in Panels A to C. Panel A controls for differential trends associated with morbidity and mortality rates of notifiable infectious diseases. Panel B controls for differential trends associated with numbers of physicians, nurses, beds, and general hospitals. Panel C controls for differential trends associated with GDP, government expenditure, population, and proportion of old adults aged above 65. In Panel D, we interact the survey wave dummies with the duration of the SARS epidemic in each province and the omitted time category is the 1998 wave. Old adults surveyed in 2002 belong to the post-epidemic group since their mortality data were observed after 2003. Panel E controls for a binary variable indicating whether the respondent was enrolled in the NRCMS. The CLHLS started to collect information on NRCMS in 2005. We assume that the respondent was not enrolled in the NRCMS before 2005. Panel F controls for fixed effects for primary sources of financial support and marriage status. Panel G controls for a range of time-varying macroeconomic variables at the provincial level, including GDP, the number of hospitals, the number of physicians, and the number of hospital beds. Panel H presents robust standard errors in parentheses and two-tailed wild cluster bootstrap p-values in square brackets. Other control variables include a dummy for females, a dummy for rural areas, and years of education. Standard errors are clustered by province. ***significant at 1% level, **at 5%, *at 10%.

Table A4
Sample selection.

Variables	(1) Attrition	(2) Deceased in the Current wave	(3) Mortality within 1 year	(4) Mortality within 2 years	(5) Mortality within 3 years
SARS duration*post	−0.020	0.030***	0.014*	0.030***	0.028**
	(0.028)	(0.009)	(0.008)	(0.010)	(0.011)
Observations	77,776	55,285	54,290	53,523	48,809
R-squared	0.052	0.135	0.044	0.097	0.144
Year FE	YES	YES	YES	YES	YES
Province FE	YES	YES	YES	YES	YES
Age group FE	YES	YES	YES	YES	YES
Other control	YES	YES	YES	YES	YES

Note: In Column (1), we additionally include the sample who was lost to follow-up during the survey, and the dependent variable is a dummy variable indicating the respondent dropped out from the study. In Columns (2) to (3), we exclude those aged less than 78 in our baseline sample. Other control variables include a dummy for females, a dummy for rural areas, and years of education. Standard errors are clustered by province. ***significant at 1% level, **at 5%, *at 10%.

Table A5
Alternative measures of SARS exposure.

Variables	(1) Mortality within survey interval	(2) Mortality within 1 year	(3) Mortality within 2 years	(4) Mortality within 3 years
Panel A. Provincial level infection rate rank				
Infection rate rank*post	0.003***	0.001	0.002**	0.003**
	(0.001)	(0.001)	(0.001)	(0.001)
Observation	67,034	65,996	65,229	58,314
Panel B. Provincial level death rate rank				
Death rate rank*post	0.003	0.002	0.002	0.003
	(0.002)	(0.001)	(0.002)	(0.002)
Observation	67,034	65,996	65,229	58,314
Panel C. Provincial level infection rate				
Infection rate*post	0.202**	0.149**	0.153	0.129
	(0.080)	(0.064)	(0.094)	(0.102)
Observation	66,033	65,045	64,294	57,501
Panel D. Provincial level death rate				
Death rate*post	3.493	2.687	2.042	1.672
	(2.412)	(1.662)	(2.738)	(3.113)
	66,033	65,045	64,294	57,501
Panel E. Prefectural level infection rate				
Infection rate*post	0.044***	0.012**	0.031**	0.065***

(*continued on next page*)

Table A5 (*continued*)

Variables	(1)	(2)	(3)	(4)
	Mortality within survey interval	Mortality within 1 year	Mortality within 2 years	Mortality within 3 years
	(0.011)	(0.006)	(0.013)	(0.016)
Observation	58,665	57,701	57,079	51,411
Year FE	YES	YES	YES	YES
Age group FE	YES	YES	YES	YES
Other control	YES	YES	YES	YES

Note: All cells report the DID estimates from separate regressions. Panels A and B use the whole sample. Panels C to E exclude the Beijing sample. In Panels A to D, other control variables include dummies for province, a dummy for females, a dummy for rural areas, and years of education, and standard errors are clustered by province. In Panel E, other control variables include dummies for cities, a dummy for females, a dummy for rural areas, and years of education, and standard errors are clustered by city. ***significant at 1% level, **at 5%, *at 10%.

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